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Trace elements and heavy metals in poultry and livestock meat in Taiwan

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Trace elements and heavy metals were determined in poultry and livestock meat by inductively coupled plasma mass spectrometry after graphite block digestion. Samples were collected from markets in Taiwan and included beef (20), mutton (20), pork (30), chicken (30), duck (10) and goose (10). Mean concentrations of Mn, Co, As, Se, Mo, Cd, Sb and Pb in meat samples were 0.106–0.365 µg/g, 0.002–0.033 µg/g, 0.005–0.035 µg/g, 0.108–0.349 µg/g, 0.029–0.140 µg/g, <0.002–0.003 µg/g, <0.002–0.004 µg/g and 0.009–0.046 µg/g, respectively. Arsenic concentrations in both pork and chicken were higher than in other meat. Lead concentrations were higher in duck. Risk assessment from these data did not indicate harm for public health.

Keywords: poultry; beef; mutton; pork; meat; trace element; heavy metal; inductively coupled plasma mass spectrometry

Introduction

Arsenic (As), lead (Pb) and cadmium (Cd) can be taken up from soil by plants and thus be eaten by animals. Food is usually the main source of human exposure to elements. Food rarely causes acute intoxications, but As, Pb and Cd accumulate into the body with possible subclinical adverse effects. The World Health Organization (WHO) concluded that even low levels of As, Pb and Cd can cause diseases in humans (WHO 1977, 1992, 2001). Trace elements, such as manganese (Mn), cobalt (Co), selenium (Se), molybdenum (Mo) and antimony (Sb), may also present in high concentrations in food, and excessive dietary intake of these elements can also have adverse effects on health. To assess risk to human health, information about elemental concentrations in food products and dietary intake is important.

Surveys to determine the levels of heavy metals and trace elements in poultry and livestock meat have been conducted in many countries, e.g. Holland (Tahvonen 1996), Sweden (Jorhem & Sundstrom 1993; Tahvonen 1996), Kazakhstan (Farmer & Farmer 2000), Egypt (Abou-Arab 2001), Germany (Tahvonen 1996), Italy (Sacco et al. 2005), Nigeria (Onianwa et al. 2000), Chile (Munoz et al. 2005), Turkey (Demirezen & Uruc 2006), Brazil (Santos et al. 2004), India (Tripathi et al. 1997), USA (Tahvonen 1996), Canada (Tahvonen 1996), Spain (Tahvonen 1996) and Finland (Tahvonen 1996) but not in Taiwan. The aim of this study was to assess As, Pb, Cd, Mn, Co, Se, Mo and Sb concentrations in poultry and livestock meat consumed in Taiwan. Moreover, estimated dietary intakes were compared with provisional tolerable weekly intakes (PTWI) or provisional tolerable monthly intakes (PTMI) established by the WHO (WHO 2011a, 2011b).

Materials and methods

Sampling

A total of 120 poultry and livestock meat samples were collected from supermarkets and traditional markets in Taipei, Taiwan. Livestock meat included 20 beef, 20 mutton and 30 pork samples. Poultry included 30 chicken, 10 duck and 10 goose samples. After purchase, samples were ground and homogenised, sealed in PE bags and kept in the freezer at –18°C until analysis. Moisture content of the samples was determined based on fresh and dried sample weight.

Reagents and reference material

All chemicals used were of suprapure grade unless stated otherwise. Multi-element standard solutions (100 µg/ml) and mass spectrometer tuning solutions were purchased from Perkin Elmer (Waltham, MA, USA). Rhodium standard solution (1000 µg/ml), nitric acid and hydrogen peroxide were purchased from E. Merck (Darmstadt, Germany). Reference material RM 8414, lyophilised bovine muscle, was obtained from the National Institute of Standards and Technology (Gaithersburg, MD, USA). Milli-Q quality water (Millipore, Bedford, MA, USA) was used.

Instrumentation

The block digester *Digi*PREP MS was a product of SCP Science (Quebec, Canada). The inductively coupled plasma mass spectrometer (ICP-MS) Elan DRC-e with a concentric nebuliser and cyclonic spray chamber was a product of Perkin-Elmer Sciex (Waltham, MA, USA). All

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volumetric bottles and other glassware were Pyrex brand. Before use, these were washed with detergent and water, soaked with 50% (v/v) nitric acid overnight, rinsed with water and dried.

Procedure

A sample portion of 0.5 g tissue (fresh weight) was weighted and put into the digestion vessel, and 6 ml nitric acid and 1.5 ml hydrogen peroxide were added. The mixture was placed on the block digester and gradually heated to 95°C until the vapour and the acid fluid inside the vessel turned clear. The digests were quantified into 20 ml in a volumetric flask. As, Pb, Cd, Mn, Co, Se, Mo and Sb concentrations were determined by ICP-MS using rhodium as internal standard. Calibration graphs were obtained with concentrations between 0.1 and 25 ng/ml. Recoveries were tested on spiked samples at 100, 200 and 500 ng/g.

Quality control

The analytical method used was verified by analysing reference material NIST RM 8414. The limit of quantification was calculated as ten times the standard deviation of the blank (n = 10) and was based on the mean sample weight analysed.

Results and discussion

Standard curves, recoveries and detection limits

Calibration curve slopes, intercepts and regression coefficients are listed in Table 1. Recoveries were 87.0–94.0% for As, 87.8–122.5% for Pb, 82.4–90.6% for Cd, 70.2–103.5% for Mn, 75.7–100.3% for Co, 53.6–105.8% for Se, 112.5–123.5% for Mo and 93.1–106.3% for Sb in poultry; and 90.9–118.8 for As, 92.8–122.7% for Pb, 82.4–91.5% for Cd, 98.3–128.3% for Mn, 89.3–112.4% for Co, 88.6–137.9% for Se, 108.3–125.4% for Mo and 93.1–105.4% for Sb in livestock meat. The precision of the analytical method, calculated as the relative standard deviation (RSD) of heavy metal concentrations in 10 digests of the same sample, was between 5.9 and 9.7%. The limits of quantification (LOQs) of As, Pb, Cd, Mn, Co, Se, Mo and Sb were 0.002 µg/g. Differences between certified values for the reference material NIST RM 8414 and measured concentrations were below 10% (Table 2), which indicates that the method was well able to analyse heavy metals in poultry and livestock meat.

Table 1. Linear equations and correlation coefficients for ICP-MS analysis.

Element	Linear equation	Correlation coefficient (R^2)
Mn-55	$y = 38564x + 7164.9$	0.9999
Co-59	$y = 31660x + 2628.3$	0.9999
As-75	$y = 4370.1x + 15.8$	1
Se-78	$y = 1281.4x + 5100$	1
Mo-98	$y = 13051x + 252.9$	1
Cd-112	$y = 12809x + 780.3$	1
Cd-114	$y = 15967x + 932.4$	0.9999
Sb-121	$y = 21075x + 1525.6$	0.9999
Sb-123	$y = 16474x + 808.9$	1
Pb-206	$y = 24292x + 4387.6$	0.9998
Pb-207	$y = 21335x + 2200.7$	1
Pb-208	$y = 49705x + 9678.6$	0.9998

Heavy metal concentrations in poultry and livestock meat

Analytical results are summarised in Table 3. As levels in beef, chicken and pork were lower than found by Schoof et al. (1996), who found 0.515 µg/g in beef, 0.0135 µg/g in pork and 0.0864 µg/g in chicken.

Pb levels in beef were similar to the values found in beef steak and muscle in Holland and Germany, where Tahvonen (1996) measured 0.010 ± 0.060 and 0.011 ± 0.007 µg/g, and in Sweden, where <0.005 ± 0.001 µg/g (Tahvonen 1996) and <0.005 µg/g (Jorhem & Sundstrom 1993), were found respectively. Pb levels were clearly lower than encountered in bovine and buffalo muscle in Egyptian rural areas, where 0.061 ± 0.03 and 0.052 ± 0.02 µg/g, and in industrial areas, where 0.093 ± 0.04 and 0.081 ± 0.03 µg/g, repectively, were measured (Abou-Arab 2001). In cattle muscle in Kazakhstan, 0.67 ± 0.08, 0.71 ± 0.09, 0.77 ± 0.08 and 0.61 ± 0.06 µg/g were found (Farmer & Farmer 2000). Pb levels in mutton were similar to thosefound in sheep and goat muscle in Egyptian rural areas, where 0.010 ± 0.01 and 0.012 ± 0.01 µg/g were reported, respectively (Abou-Arab 2001). Concentrations were lower than in sheep muscle in Germany, where 0.017 µg/g was found (Tahvonen 1996), and sheep and goat muscle in Egyptian industrial areas, where 0.081 ± 0.03 and 0.084 ± 0.04 µg/g, respectively, were reported (Abou-Arab 2001). Pb in pork was slightly higher

Table 2. Determination of elements in meat reference material (NIST RM-8414).

Element	Found* (mg/kg)	Certified values** (mg/kg)
Mn	0.37 ± 0.08	0.37 ± 0.09
Co	0.006 ± 0.002	0.007 ± 0.003
As	0.008 ± 0.001	0.009 ± 0.003
Se	0.080 ± 0.003	0.076 ± 0.010
Mo	0.06 ± 0.01	0.08 ± 0.06
Cd	0.011 ± 0.002	0.013 ± 0.011
Sb	0.014 ± 0.001	(0.01)***
Pb	0.38 ± 0.19	0.38 ± 0.24

Notes: *Mean ± S.D. (n = 5). **Content and uncertainty. ***Values in parentheses are for information only.

Table 3. Survey results of heavy metals in different meat in Taiwan.

Sample Concentration (μg/g)	Mn	Co	As	Se	Mo	Cd	Sb	Pb
Beef	0.148 ± 0.048 (0.093–0.299)	0.033 ± 0.009 (<0.002–0.041)	0.008 ± 0.009 (<0.002–0.041)	0.139 ± 0.037 (0.061–0.187)	0.033 ± 0.074 (<0.002–0.286)	<0.002	<0.002	0.009 ± 0.0.08 (<0.002–0.030)
Mutton	0.284 ± 0.081 (0.152–0.491)	0.003 ± 0.002 (<0.002–0.007)	0.005 ± 0.003 (<0.002–0.013)	0.108 ± 0.181 (0.014–0.836)	0.029 ± 0.041 (0.002–0.148)	0.002 ± 0.004 (<0.002–0.017)	0.004 ± 0.010 (<0.002–0.035)	0.009 ± 0.007 (<0.002–0.026)
Pork	0.106 ± 0.059 (<0.002–0.218)	0.002 ± 0.002 (<0.002–0.005)	0.018 ± 0.027 (0.002–0.075)	0.212 ± 0.045 (0.115–0.309)	0.140 ± 0.153 (0.007–0.603)	0.003 ± 0.011 (<0.002–0.051)	<0.002	0.013 ± 0.021 (<0.002–0.098)
Duck	0.365 ± 0.084 (0.265–0.541)	0.005 ± 0.003 (<0.002–0.008)	0.012 ± 0.004 (0.005–0.016)	0.349 ± 0.097 (0.201–0.199)	0.098 ± 0.070 (0.017–0.205)	0.036 ± 0.042 (<0.002–0.103)	<0.002	0.046 ± 0.098 (0.002–0.321)
Goose	0.268 ± 0.073 (0.151–0.367)	0.005 ± 0.002 (0.004–0.009)	0.011 ± 0.005 (0.004–0.022)	0.346 ± 0.088 (0.221–0.498)	0.070 ± 0.023 (0.045–0.113)	<0.002	0.002 ± 0.001 (<0.002–0.004)	0.021 ± 0.014 (0.008–0.051)

Table 4. Risk analysis of arsenic, lead and cadmium in meat.

				Concentration (μg/g)						Week intake (μg/week)					
				Mean			Maximum			Mean			Maximum		
Meat			Dairy intake (g)	As	Pb	Cd	As	Pb	Cd	As	Pb	Cd	As	Pb	Cd
Male	Livestock meat	Pork	126.19 (62.2%)	0.018	0.013	0.003	0.075	0.098	0.051	15.90 (52.3%)	11.48 (66.9%)	2.65 (44.8%)	66.25 (68.1%)	86.57 (77.2%)	45.05 (85.0%)
		Beef	7.86 (3.9%)	0.008	0.009	0.002	0.041	0.030	<0.002	0.44 (1.4%)	0.50 (2.9%)	0.11 (1.9%)	2.26 (2.3%)	1.65 (1.5%)	0.11 (0.2%)
		Other	3.3 (1.6%)	0.005	0.009	0.002	0.013	0.026	0.017	0.12 (0.4%)	0.21 (1.2%)	0.05 (0.8%)	0.30 (0.3%)	0.60 (0.5%)	0.39 (0.7%)
	Poultry	Chicken	52.51 (25.9%)	0.035	0.004	0.002	0.073	0.024	<0.002	12.88 (42.4%)	1.47 (8.6%)	0.74 (12.4%)	26.83 (27.6%)	1.26 (1.1%)	0.74 (1.4%)
		Duck	9.21 (4.5%)	0.012	0.046	0.036	0.016	0.321	0.103	0.77 (2.5%)	2.97 (17.3%)	2.32 (39.2%)	1.03 (1.1%)	20.69 (18.5%)	6.64 (12.5%)
		Other	3.76 (1.9%)	0.011	0.021	0.002	0.022	0.051	<0.002	0.29 (1.0%)	0.55 (3.2%)	0.05 (0.9%)	0.58 (0.6%)	1.34 (1.2%)	0.05 (0.1%)
Total week intake (μg/week)										30.40	17.18	5.92	97.25	112.11	52.98
Percentage of the PTWI or PTMI due to consumption of meat products													10.8%*	7.5%	15.1%
Female	Livestock meat	Pork	88.2 (67.9%)	0.018	0.013	0.003	0.075	0.098	0.051	11.11 (57.2%)	8.03 (75.1%)	1.85 (56.8%)	46.31 (72.4%)	60.51 (85.4%)	31.49 (90.9%)
		Beef	3.12 (2.4%)	0.008	0.009	0.002	0.041	0.030	<0.002	0.17 (0.9%)	0.20 (1.8%)	0.04 (1.3%)	0.90 (1.4%)	0.66 (0.9%)	0.04 (0.1%)
		Other	1.33 (1.0%)	0.005	0.009	0.002	0.013	0.026	0.017	0.05 (0.2%)	0.08 (0.8%)	0.02 (0.6%)	0.12 (0.2%)	0.24 (0.3%)	0.16 (0.5%)
	Poultry	Chicken	31.06 (23.9%)	0.035	0.004	0.002	0.073	0.024	<0.002	7.61 (39.1%)	0.87 (8.1%)	0.43 (13.3%)	15.87 (24.8%)	0.74 (1.0%)	0.43 (1.2%)
		Duck	3.46 (2.7%)	0.012	0.046	0.036	0.016	0.321	0.103	0.29 (1.5%)	1.11 (10.4%)	0.87 (26.8%)	0.39 (0.6%)	7.77 (11.0%)	2.49 (7.2%)
		Other	2.66 (2.0%)	0.011	0.021	0.002	0.022	0.051	<0.002	0.20 (1.1%)	0.39 (3.7%)	0.04 (1.1%)	0.41 (0.6%)	0.95 (1.3%)	0.04 (0.1%)
Total week intake (μg/week)										19.44	10.68	3.26	64.00	70.87	34.65
Percentage of the PTWI or PTMI due to consumption of meat products													7.1%	4.7%	9.9%

Note: *PTWI, provisional tolerable weekly intake for Pb: 25 μg/kg body weight (WHO 2011b); As: 15 μg inorganic arsenic/kg body weight (WHO 2011a), *PTMI, provisional tolerable monthly intake for Cd: 25 μg/kg body weight (WHO 2011b).

than in pig muscle in Germany, where 0.009 μg/g was found (Tahvonen 1996), and in Sweden, where <0.005 ± 0.002 μg/g was reported (Jorhem & Sundstrom 1993).

Cd in beef was clearly lower than 0.0266 and 0.023 μg/g as found in beef steak in Canada and veal in Spain, respectively (Tahvonen 1996). For beef in Nigeria, 0.14 μg/g was reported (Onianwa et al. 2000); for cattle muscle in Kazakhstan, 0.05 ± 0.01, 0.08 ± 0.01, 0.02 ± 0.003 and 0.42 ± 0.11 μg/g were found (Farmer & Farmer 2000); and in Egypt in bovine and buffalo muscle in rural areas 0.010 ± 0.01 and 0.006 ± 0.004 μg/g and in industrial areas 0.031 ± 0.02 and 0.011 ± 0.01 μg/g, respectively, were found (Abou-Arab 2001).

Mn levels in beef were slightly higher than 0.093 ± 0.044 μg/g measured by Jorhem and Sundstrom (1993) in Sweden and clearly lower than encountered in bovine and buffalo muscle in Egyptian rural areas, where 1.1 ± 0.8 and 0.9 ± 0.4 μg/g, and in industrial areas, where 1.4 ± 1.0 and 0.9 ± 0.3 μg/g were found (Abou-Arab 2001). In mutton, lower levels were measured than was found in lamb meat in five areas in Italy, where 0.477 ± 0.091, 0.375 ± 0.078, 0.455 ± 0.122, 0.475 ± 0.126 and 0.435 ± 0.094 μg/g were found (Sacco et al. 2005), and sheep and goat muscle in Egyptian rural areas, where 0.8 ± 0.4 and 0.6 ± 0.4 μg/g, and in industrial areas where 1.2 ± 0.6 and 0.9 ± 0.3 μg/g were measured (Abou-Arab 2001). Mn in pork was lower than 0.12 ± 0.052 μg/g as measured in Sweden (Jorhem & Sundstrom 1993).

Co in beef and pork was slightly higher than detected in Sweden (Jorhem & Sundstrom 1993) in beef (0.001 ± 0.000 μg/g) and similar in pork (0.001 ± 0.002 μg/g). Se levels were higher than 0.032 ± 0.0099 μg/g as found in Turkish meat (Demirezen & Uruc 2006).

In Taiwan, there are currently no regulatory limits for metal levels in poultry and livestock meat. The maximum level of Pb and Cd allowable in beef, mutton, pork and poultry is regulated by CODEX STAN 230-2001 and EU Directive 1881/2006. The authorised levels for Pb and Cd are 0.1 and 0.05 mg/kg, respectively. The concentrations of these elements measured in this work are within the accepted limits, except one for Pb and three for Cd in duck meat.

Risk assessment

The estimated average As intake of male and female from meat, livestock and poultry was 30.4 and 19.5 μg/week in Taiwan, respectively (Department of Health 1999). Pork and chicken contributed most to the weekly As intake from meat: 52.3% and 42.4% for male, 57.2% and 39.1% for female. The estimated average Pb intake of male and female from meat was 17.2 and 10.7 μg/week, respectively (Table 4). Pb concentrations in duck were substantially higher than in pork, beef, chicken and others, but pork contributed most to the daily Pb intake from meat because it is consumed in greater quantity than duck: 66.9% for male and 75.1% for female. The estimated average Cd intake of male and female from meat was 5.9 and 3.3 μg/week (Table 4).

WHO proposed a PTWI for inorganic As and Pb of 15 and 25 μg/kg body weight. For Cd, a PTMI of 25 μg/kg body weight was proposed. The minor contribution of meat to the total As, Pb and Cd intake of the population of Taiwan was highlighted by its low contribution to PTWI or PTMI (Table 4). However, if maximum rather than median As, Pb and Cd concentrations measured in Taiwan livestock and poultry were used in the calculations, estimated intakes of total As, Pb and Cd from meat were 97.3, 112.1 and 53.0 μg/week for male and 64.0, 70.9 and 34.7 μg/week for female, which comprised approximately 10.8%, 7.5% and 15.1% for male and 7.1%, 4.7% and 9.9% for female of the PTWI or PTMI. These results indicate that meat generally contributes little to PTWI or PTMI.

Conclusions

Generally As, Pb, Cd, Mn, Co, Se, Mo and Sb concentrations were low in all meat samples. Pb and Cd concentrations in beef, mutton, pork and poultry regularly exceeded CODEX and EU maximum levels. Based on WHO health criteria for carcinogens, meat consumption in Taiwan does not pose a risk to human health with respect to the concentrations of As, Cd and Pb in livestock and poultry meat analysed in this study. The results show the need to monitor As, Pb and Cd levels in food to evaluate food safety for the population.

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